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On the influence of galactic magnetic fields on the shape of circumstellar bubbles

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Wind-blown bubbles around massive stars

- Massive stars create large (>>10 pc) bubbles, through their stellar wind
  - Numerical models, including stellar evolution (e.g. Gacia-Segura et al. 1996a,b; Freyer et al. ´03,´06; Dwarkadas ´05,´07; Eldridge et al. ´06; van Marle et al. ´05,´07,´08; Toala & Arthur ´11)
  - Results can be used as a fingerprint of stellar evolution
  - These models tend to take the interstellar medium as a passive background
- The interstellar medium contains magnetic fields (Rand & Kulkarni 1989; Ohno & Shibata 1993; Beck ´09; Shabala et al. ´10)
  - Galactic disk: 5-10 μG
  - Galactic bulge: 10-50 μG
  - Inside molecular clouds: 100+ μG
- Even weak interstellar magnetic fields can limit the expansion of superbubbles (Tomisaka 1990,1992; Ferriere et al. 1991)
- How does this influence the shape of circumstellar shells?

Wind driven bubble expanding in a non-magnetic ISM

- 40 $M_\odot$ star
  - MS (10^{-6} $M_\odot$/yr, 2000 km/s)
  - RSG (10^{-4} $M_\odot$/yr,10 km/s)
  - WR (10^{-5} $M_\odot$/yr,2000 km/s)
- Spherical bubble with thin, unstable shell
- Multiple shells resulting from evolutionary changes in the wind

Wind-driven expansion with B_{ISM} = 20 μG

- Elongated bubble
  - Expansion perpendicular to the field stops completely!
- No visible outer shell
  - Slight compression of field lines
- RSG and WR shells constricted by the bubble into jet-like shapes

Supernova expansion with B_{ISM} = 20 μG

- Bubble remains elongated
- Supernova remnant follows the shape of the bubble

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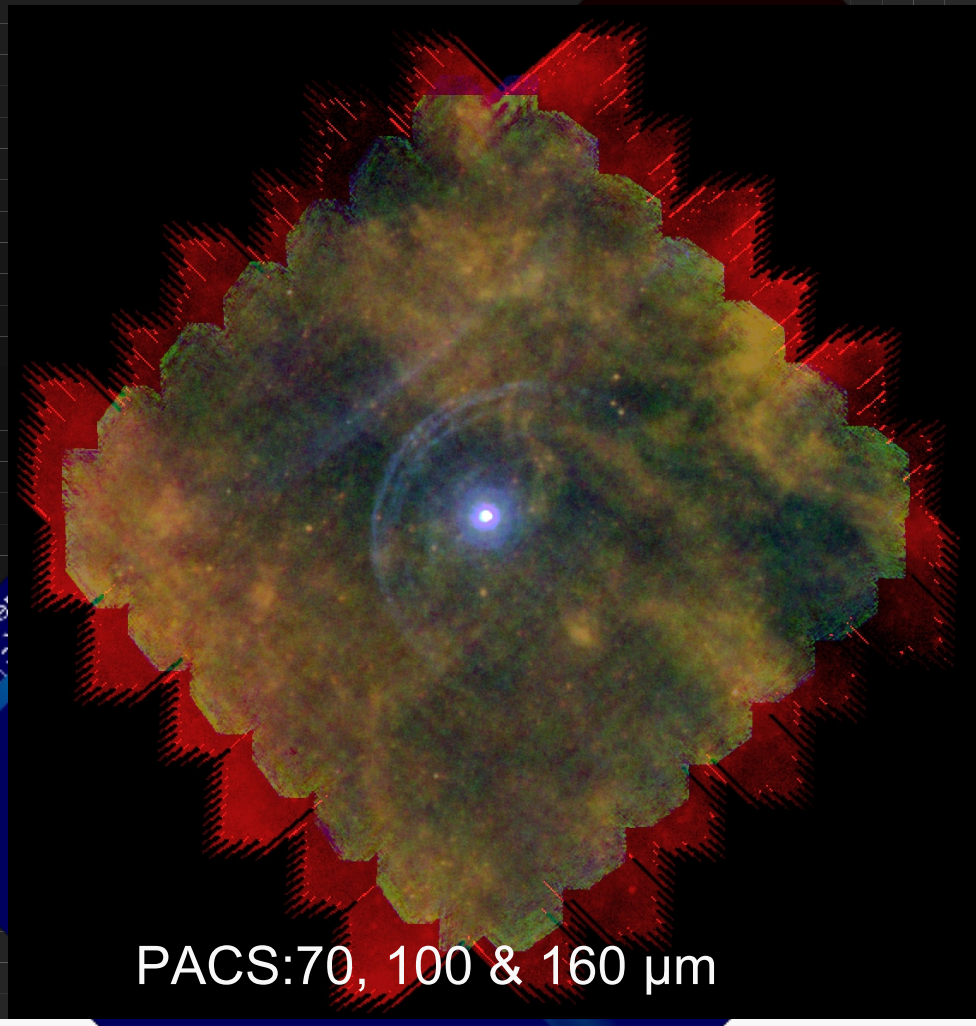
The mystery of the α-Orionis bowshock

- Red supergiant interacts with ISM: $v_w < v_*$
- Bowshock should be unstable. (e.g. Dgani et al. 1996; Brighenti & d'Ercole 1995; van Marle et al. 2011)
- But it isn't!
  - Too young? (Mohamed et al. 2012; Mackey et al. 2012)
  - Warm ISM? (Decin et al. 2012)
  - Magnetic field?



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The model:

- $\dot{M}$ = 3.0x10^{-6} $M_\odot$/yr
- V_∞ = 15 km/s
- V_* = 28.3 km/s
- ρ_{ISM} 2 #/cm^3

(Ueta et al. 2008, Decin et al. 2012)

- ISM B-field near α-Orionis
  - 1.4 - 5 μG (Frick et al. 2001, Heerikhuisen & Pogorelov 2011, Opher et al. 2009)
  - Assume 3 μG, parallel with stellar motion (to preserve 2D symmetry)

α-Orionis in an interstellar magnetic field

B = 3 μG

B = 0

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Conclusions:

- Galactic magnetic fields can influence the shape of circumstellar bubbles
- This can indirectly change the shape of temporary circumstellar shells and supernova remnants
  - Asphericity of shells may be unrelated to stellar parameters
- The lack of large scale instabilities in the bowshock of α-Orionis can be explained as the result of the local interstellar magnetic field.

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What comes next?

- Low mass stars in interstellar magnetic fields: AGB → Post-AGB (Planetary nebulae)
- Structured magnetic fields (3D)
- Bowshocks encountering non-parallel magnetic fields (3D)
- Stars in clusters (3D)